Wind energy research: An international outlook seen from Denmark

Hansen, Jens Carsten

Publication date:
2011

Document Version
Publisher's PDF, also known as Version of record

Wind energy research
an international outlook seen from Denmark

Jens Carsten Hansen

Wind Energy Division, Risø DTU

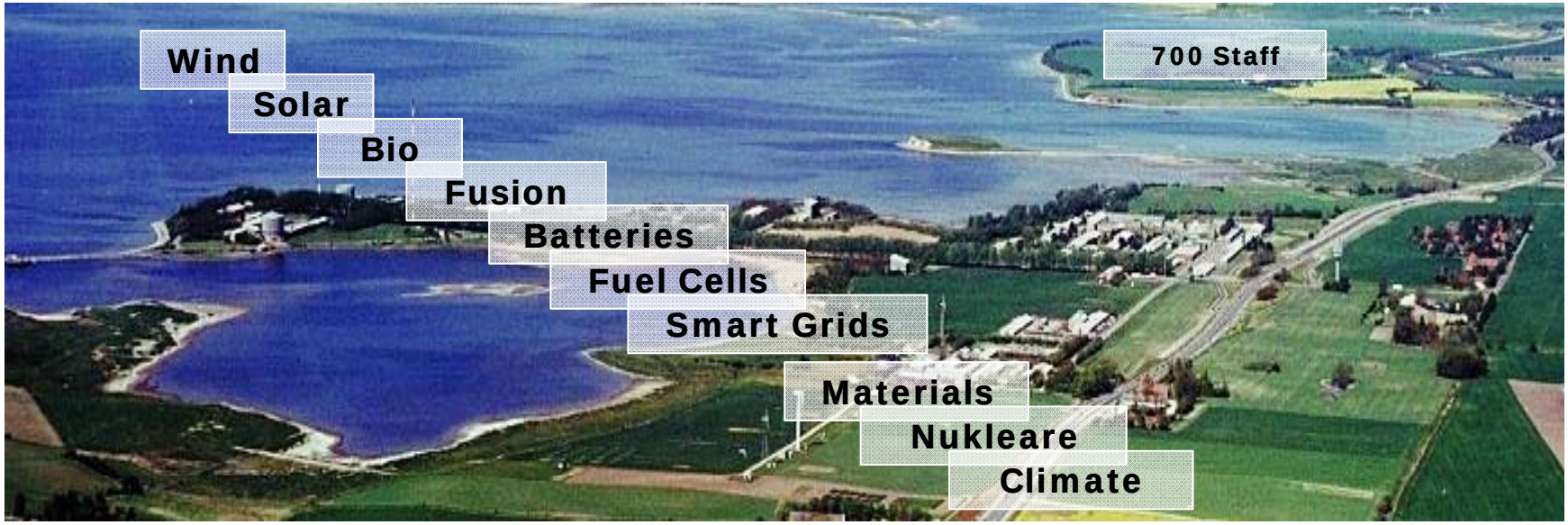
Technical University of Denmark

Outline

- Background and challenges
- Wind energy research
- International partnerships

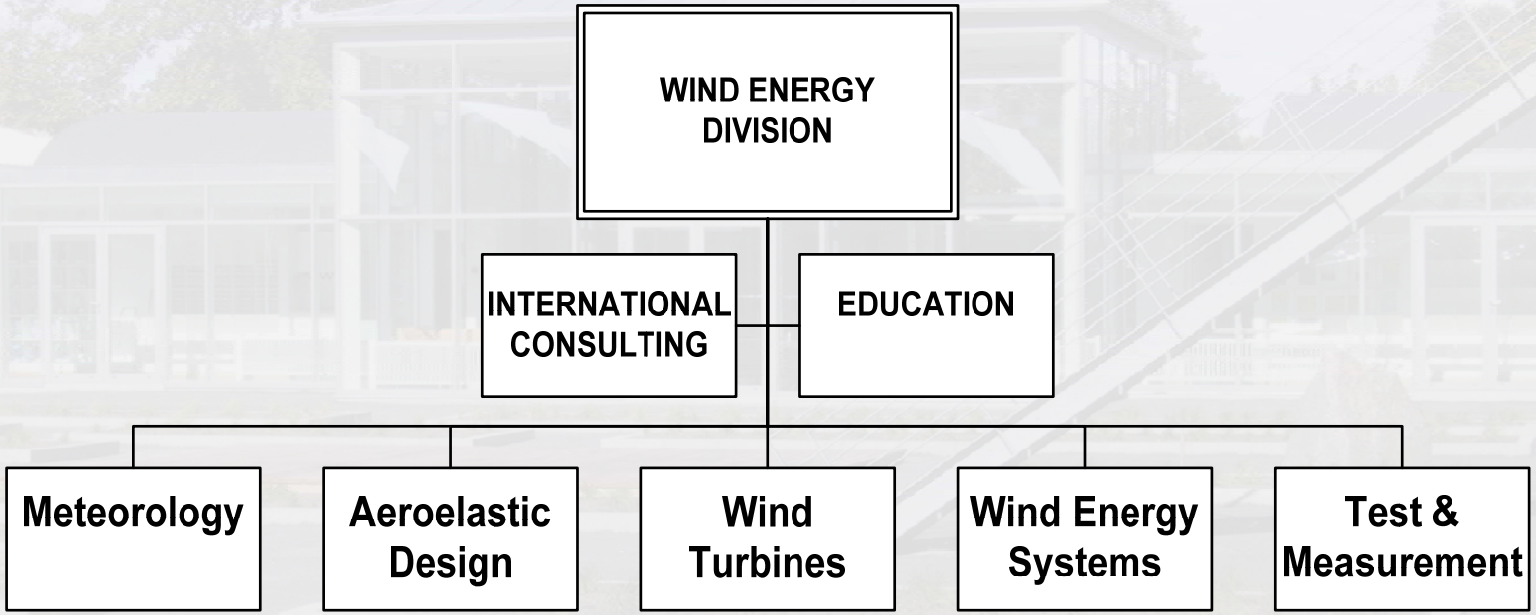
Risø DTU history in brief

- **1954** Nuclear Energy Committee headed by Niels Bohr
- **1958** 3 nuclear reactors under construction
- **1976** ***Wind energy research starts***
- **1985** No Nuclear Power in Denmark energy plans
- **2000** Decommissioning of the last nuclear reactor is
- **2005** Sustainable energy central in strategy
- **2007** ***Part of Technical University of Denmark (DTU)***



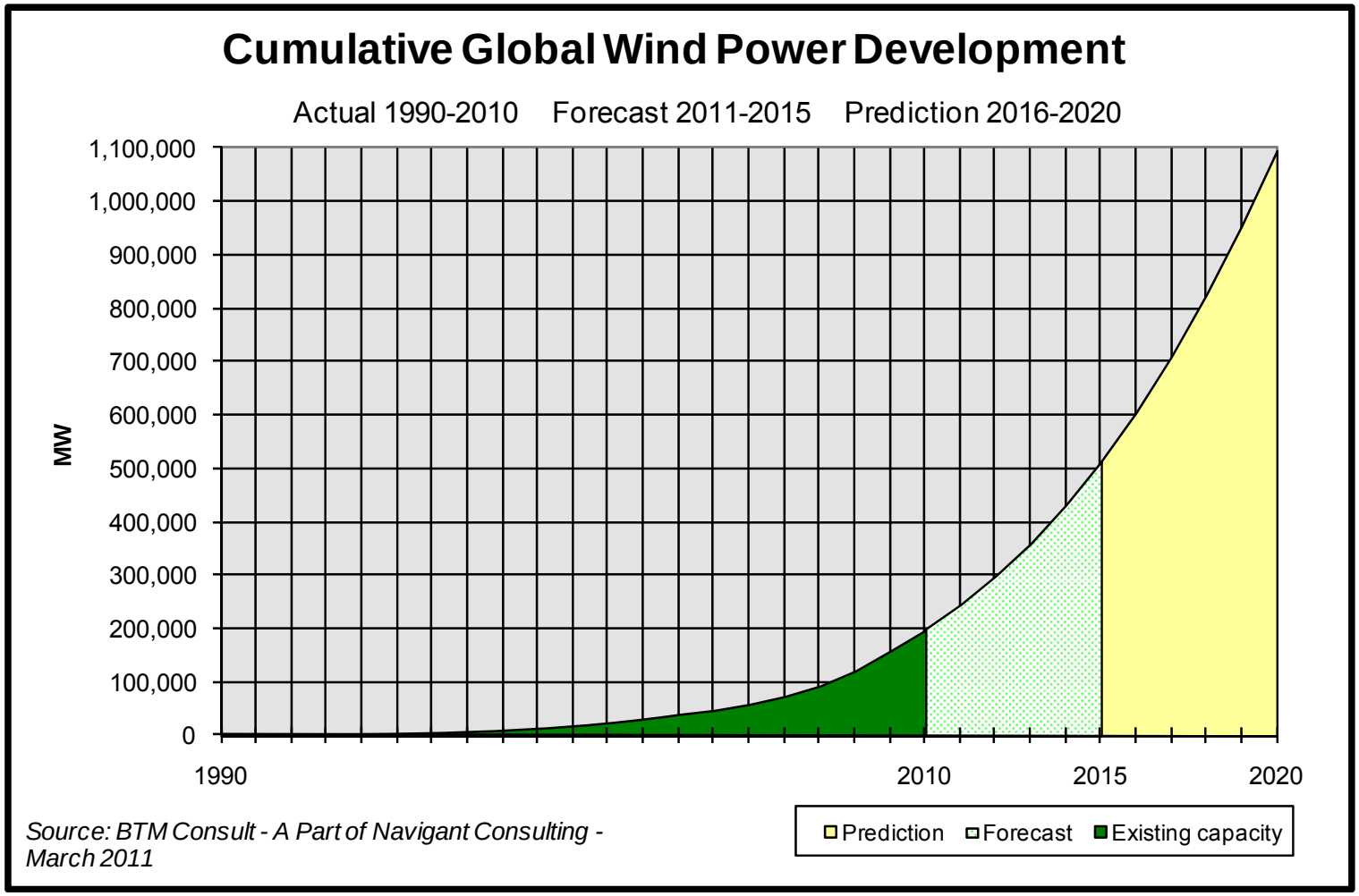
Wind Energy @ DTU

Risø DTU - Wind Energy Division (150 staff)

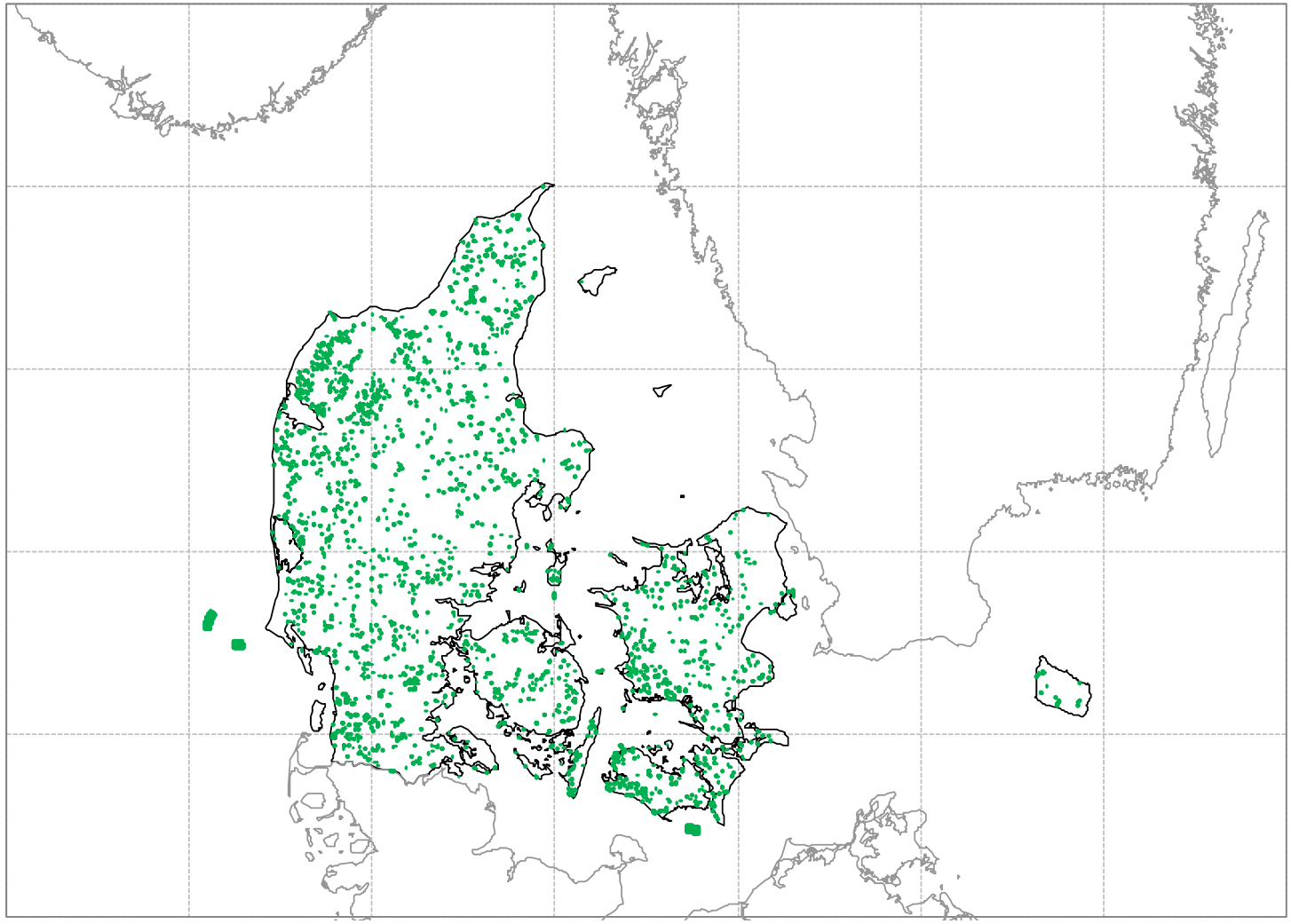


Risø DTU - Systems Analyses Division
Risø DTU - Materials Research Division
DTU-Mechanical Engineering
DTU-Electrical Engineering
DTU-Informatics

The challenge

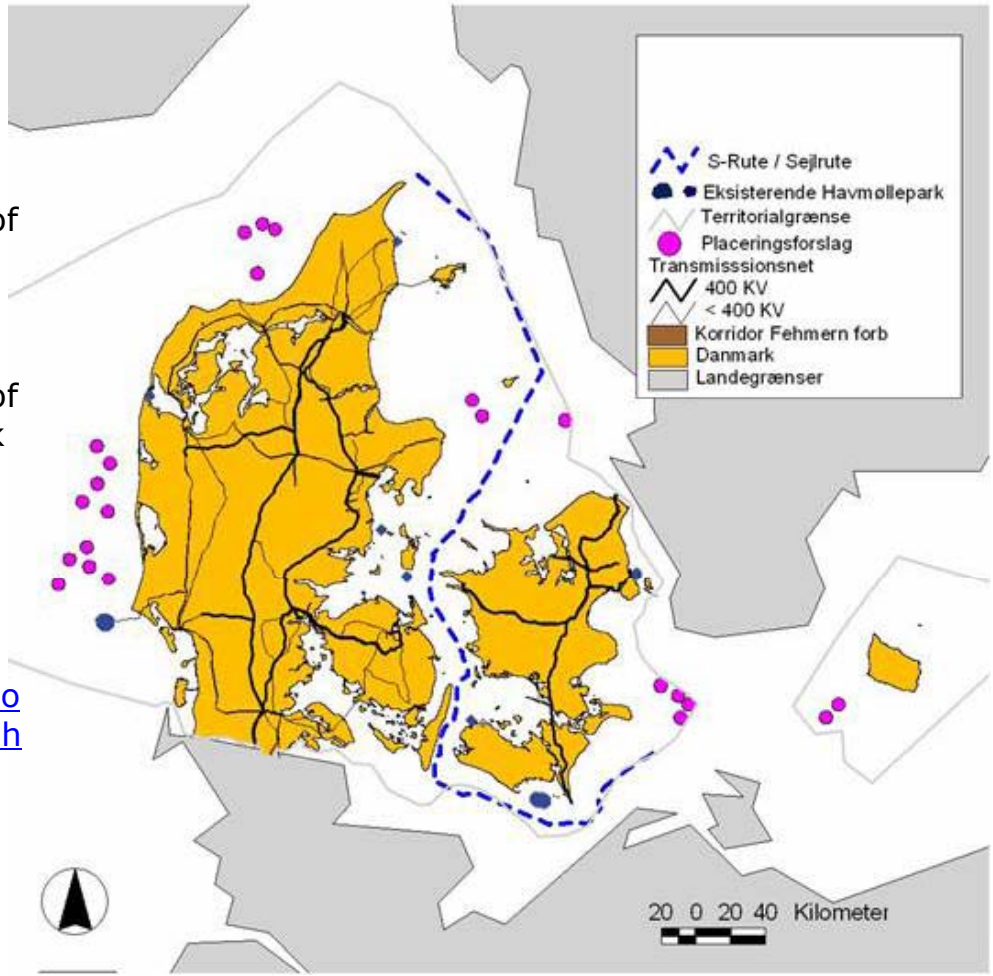


Existing wind turbines in Denmark



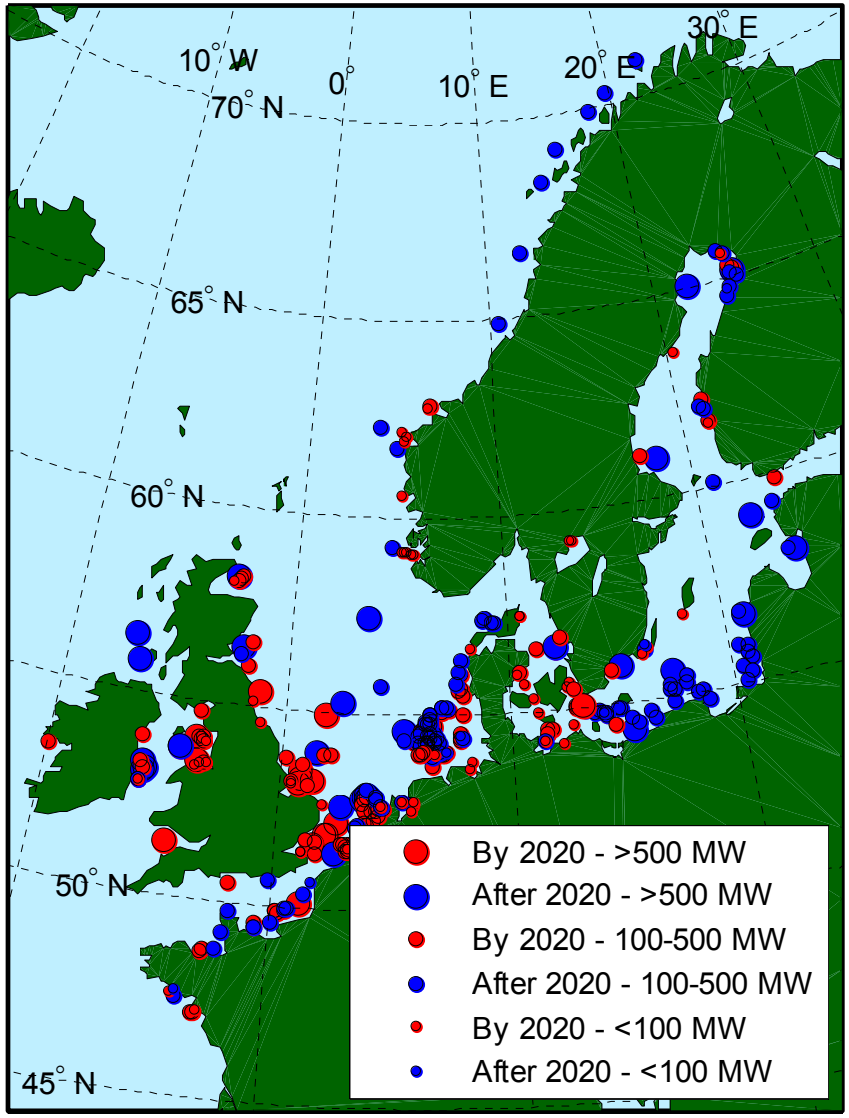
Future Danish offshore sites

- Report on future Offshore sites
- Update of action plan from 1997
- 23 Sites each 44 km2 for a capacity of 4600 MW Wind Power
- Production 18 TWh, or just over 8% of total energy consumption in Denmark or approximately 50% of Danish electricity consumption
- http://www.ens.dk/graphics/Publikationer/Havvindmoeller/Fremtidens_%20havvindm_UKsummery_aug07.pdf



Offshore wind power development scenarios

A preliminary assessment by the EU-TWENTIES project of the geographical distribution of offshore wind farms in northern Europe by 2020 and 2030



Denmark
a demonstration country for wind energy

National targets and policy

25% of electricity from wind energy today
50% of electricity from wind energy by 2020 (in new government programme)

Innovation Partnership between Research and Industry (MegaVind)

- world leading centre of competence in wind power
- **…** to provide the most effective wind power and wind power plants – that ensure the best possible integration of wind power …

Wind Energy Research

Aeroelastic Design Methods
- Aerodynamic and aeroacoustic design
- Aero-servo-elastic design
- Wind farm design
- Innovative wind turbine design

Wind Turbine Structures
- Load and safety
- Structural design of blades
- Wind turbine structures and components
- Multi-disciplinary optimization

Wind Power Meteorology
- Atmospheric flow modelling and methods for verification
- Fundamental atmospheric processes
- Wind conditions for siting and design of wind turbines

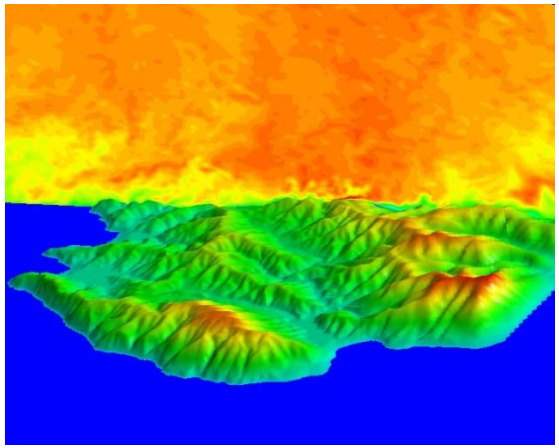
Offshore Wind Energy
- Marine wind, wave and current conditions
- Wakes in offshore wind turbine farms

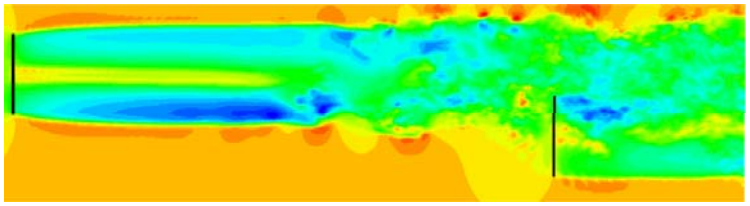
Wind power integration and control
- Wind power plants in the power system
- Variability, prediction and predictability of wind power
- Integrated design and control of wind turbines and wind farms
- Policies and strategies for wind energy research and innovation

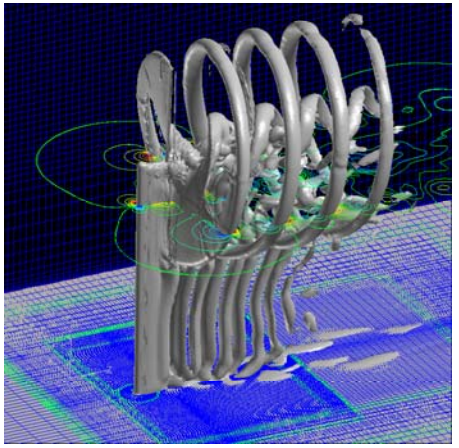
Test and measurements

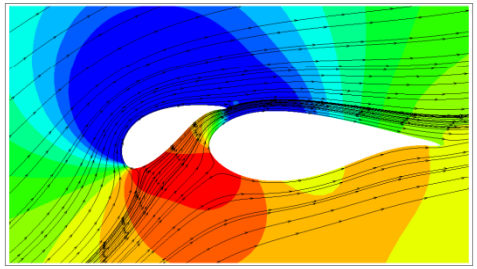
Objectives:
- To develop new opportunities and technologies for the global and Danish exploitation of wind energy;
- To improve the competitiveness of wind energy;
- To optimize the technical/scientific knowledge and competencies within the primary research areas for the development of wind energy; and
- To support the implementation and utilization of the research results in society through research-based consulting and services to industry and the public sector, innovation and education.

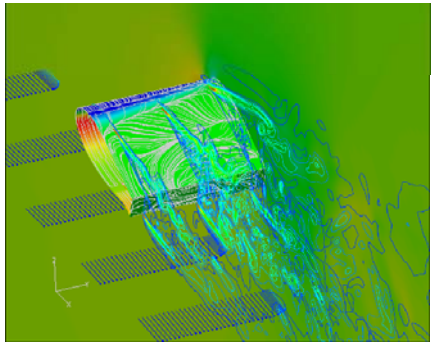
Advanced Wind Turbine Aerodynamics - modelling and experimental validation

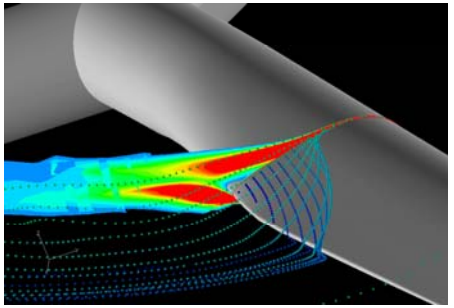










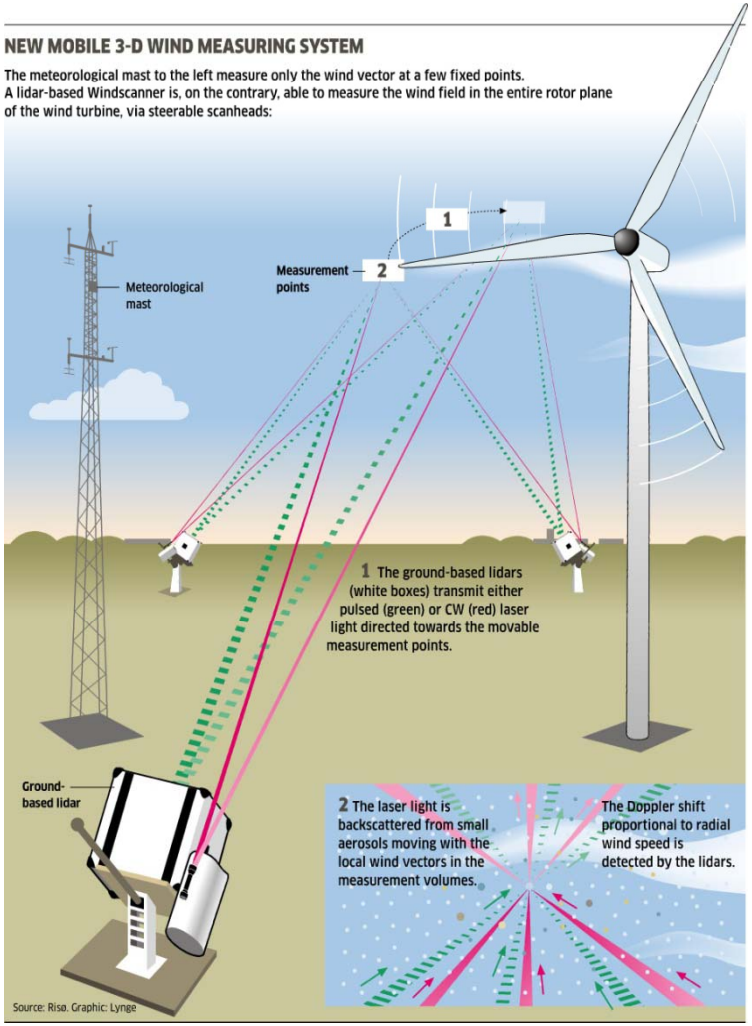


Risø Test Stations – Prototype Testing

5 test beds
< 165 m
< 8 MW
Spacing 300 m

7 test beds
< 250 m
< 16 MW
Spacing 600 m

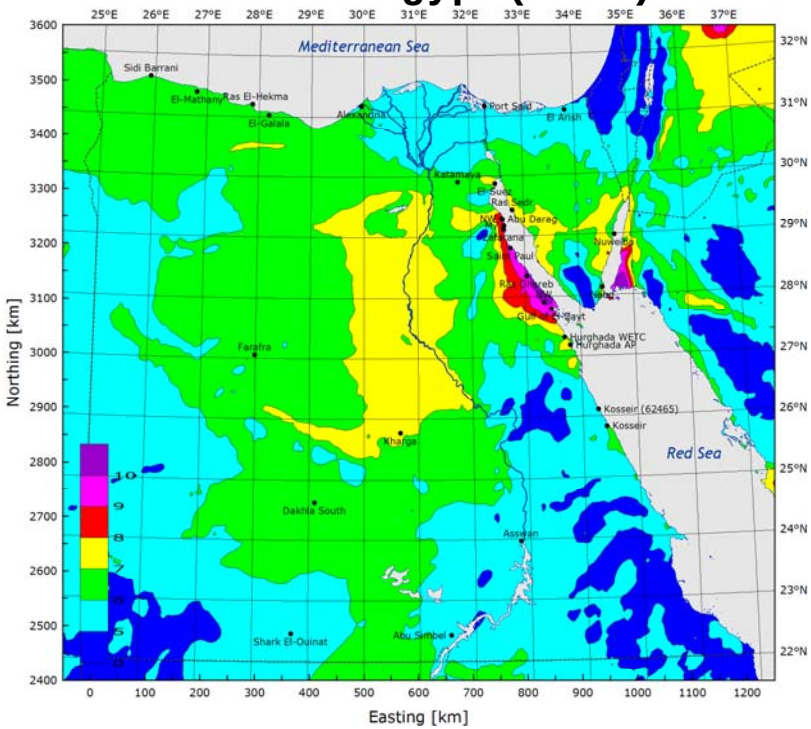
Windscanner.DK



Lidar-based wind and turbulence measurements for research, siting and control

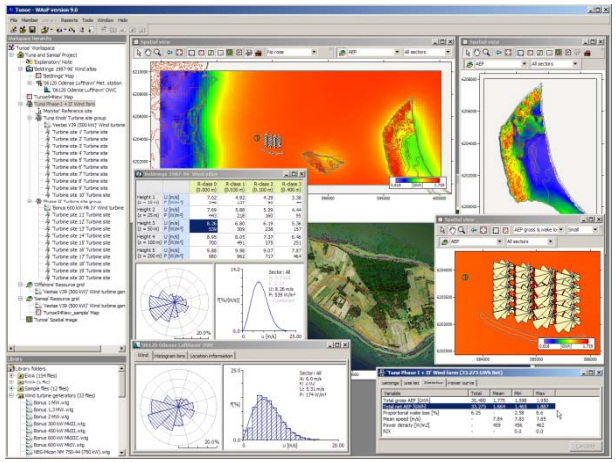
Wind Atlas Method and tools

Wind Atlas Denmark (1981)
Wind Atlas Europe (1989)
Wind Atlas for Egypt (2006)

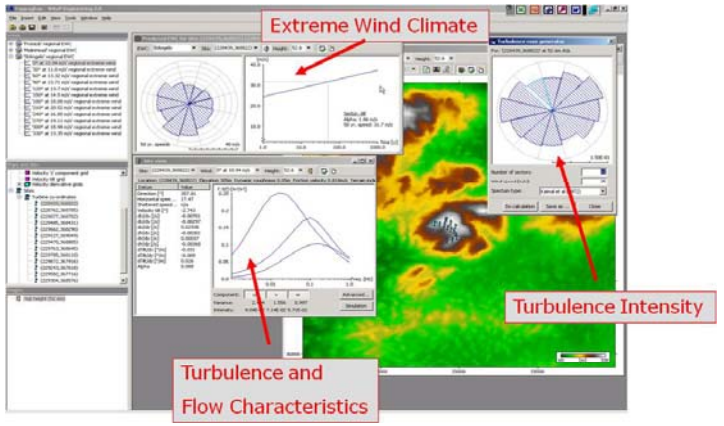


Wind Atlas India (2008)
Wind Atlas NE China (2010)
Wind Atlas South Africa (2011)
Global WA

WAsP – wind resource assessment



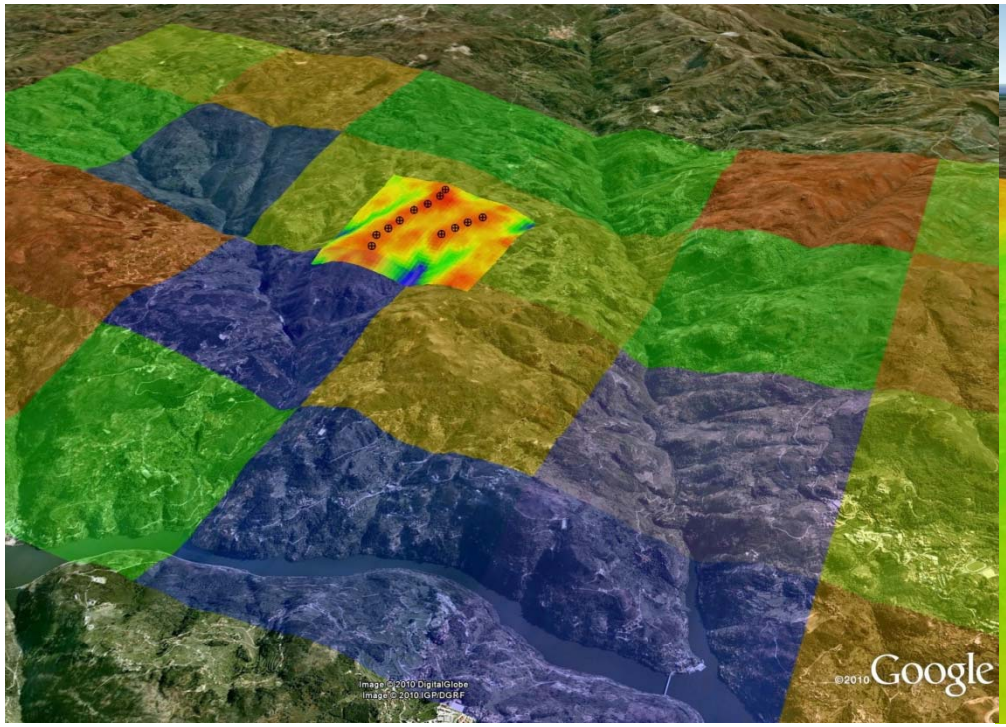
WAsP Engineering – design conditions

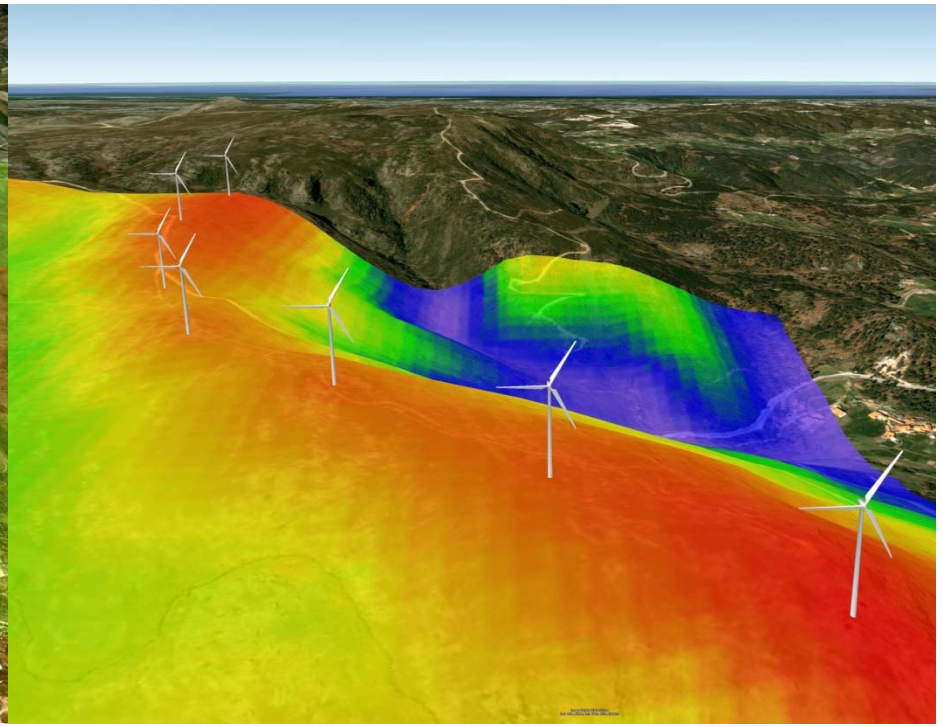


Application

Results of the "Meso-Scale and Micro-Scale Modelling in China" project, is available in public domain, containing description of the Wind Atlas Method and how to apply the Numerical Wind Atlas

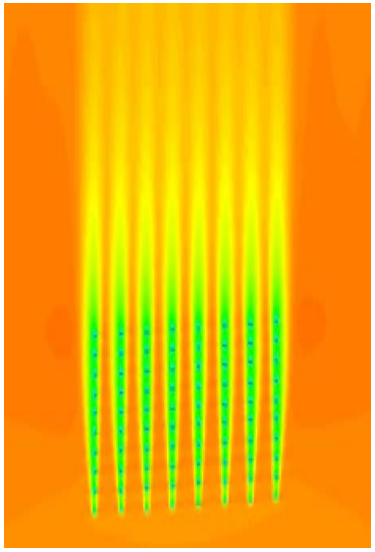
http://www.dwed.org.cn/

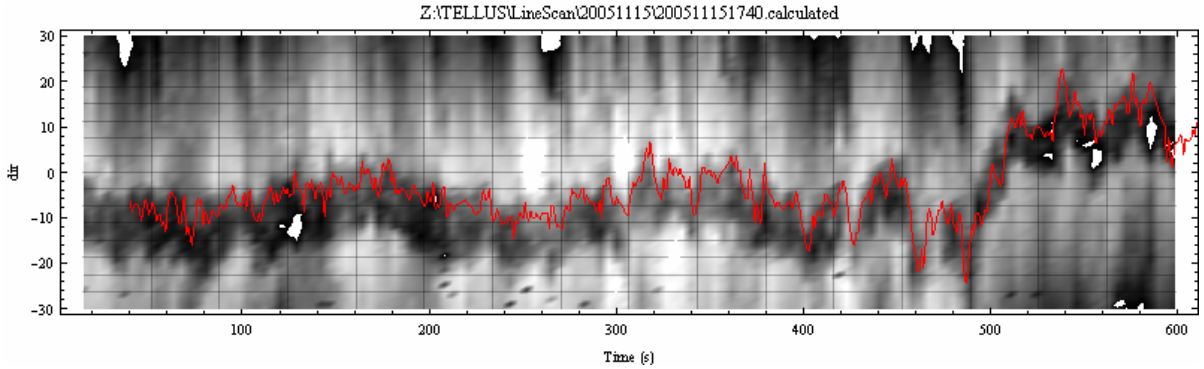




Wind Turbines in Complex Terrain
Do the models work here?

Offshore Wind Farms



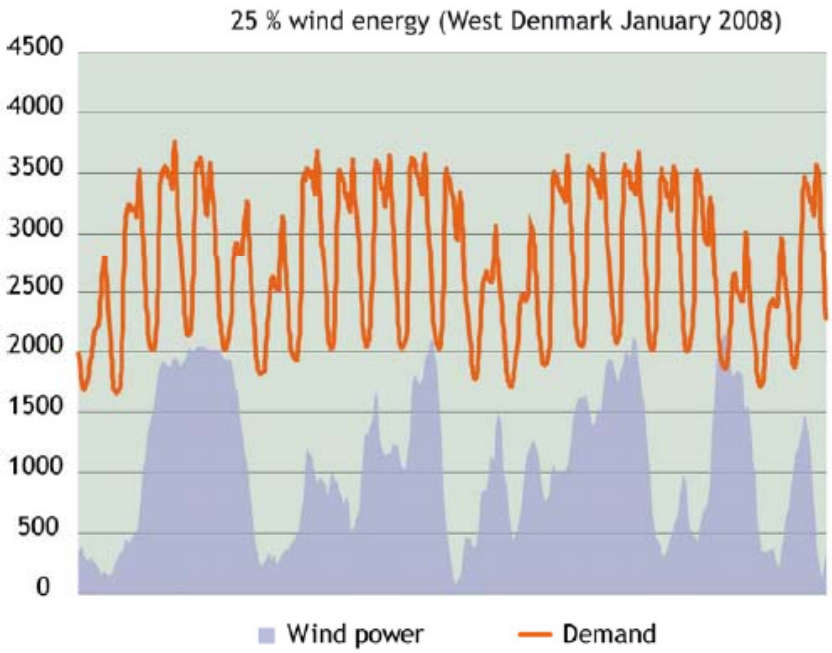


Dynamic wake meander motion

- Wind turbines wake effect
- Multiscale CFD turbulence models (ABL + wake)
- Wind farm data analysis
- Influence of atmospheric stability
- Dynamic wake meander model
- Wind farms shadow effect
- Micro-mesoscale interaction
- Wind farm layout optimization

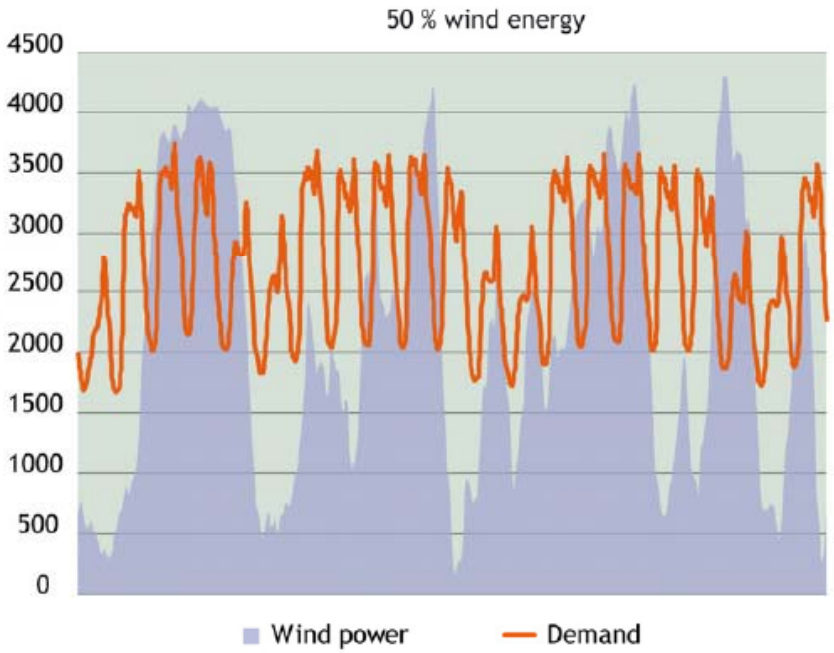
Wind integration: The Danish Target

2008



- Approximately 20% of electricity consumption met by wind power – annual average
- Around 3GW installed wind power capacity
- For a few hours in a year wind power covers the entire Danish demand

2020



- 50% of electricity consumption to be met by wind power – annual average
- Around 6GW installed wind power capacity
- Wind power production will often exceed the Danish demand

Source: Energinet.dk - EcoGrid

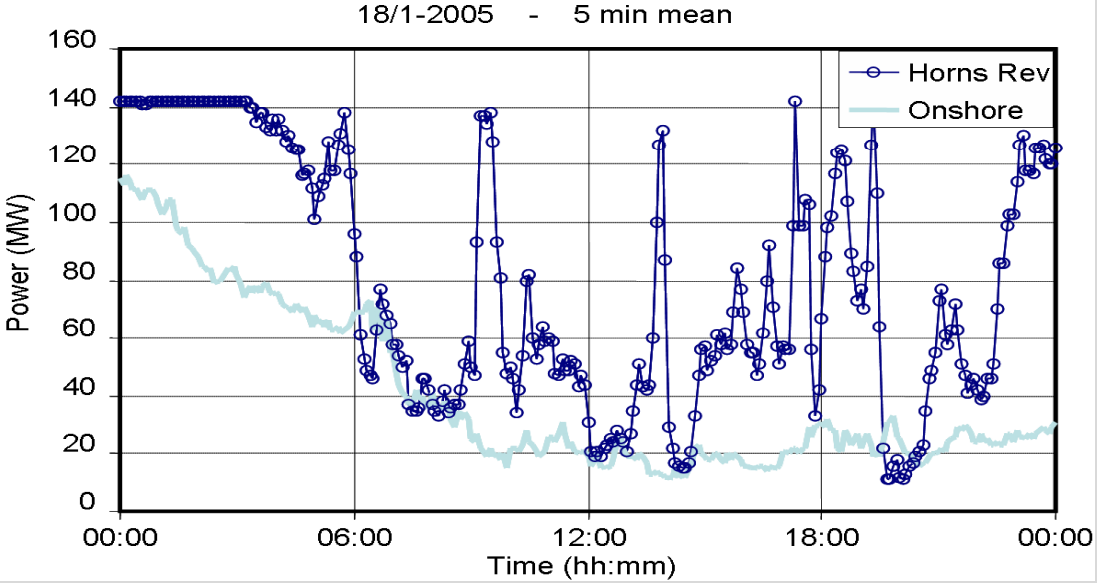
Wind power variability and prediction

Danish research efforts have as goal:

- to improve power system and wind power plant functionality
- to seek solutions to enable integration of large amounts of wind power
- to assure the security and reliability of power supply in power systems with large amounts of wind power

Relevance for planning, design and operation !

Example of Horns Rev wind farm



Source: DONG Energy and Vattenfall

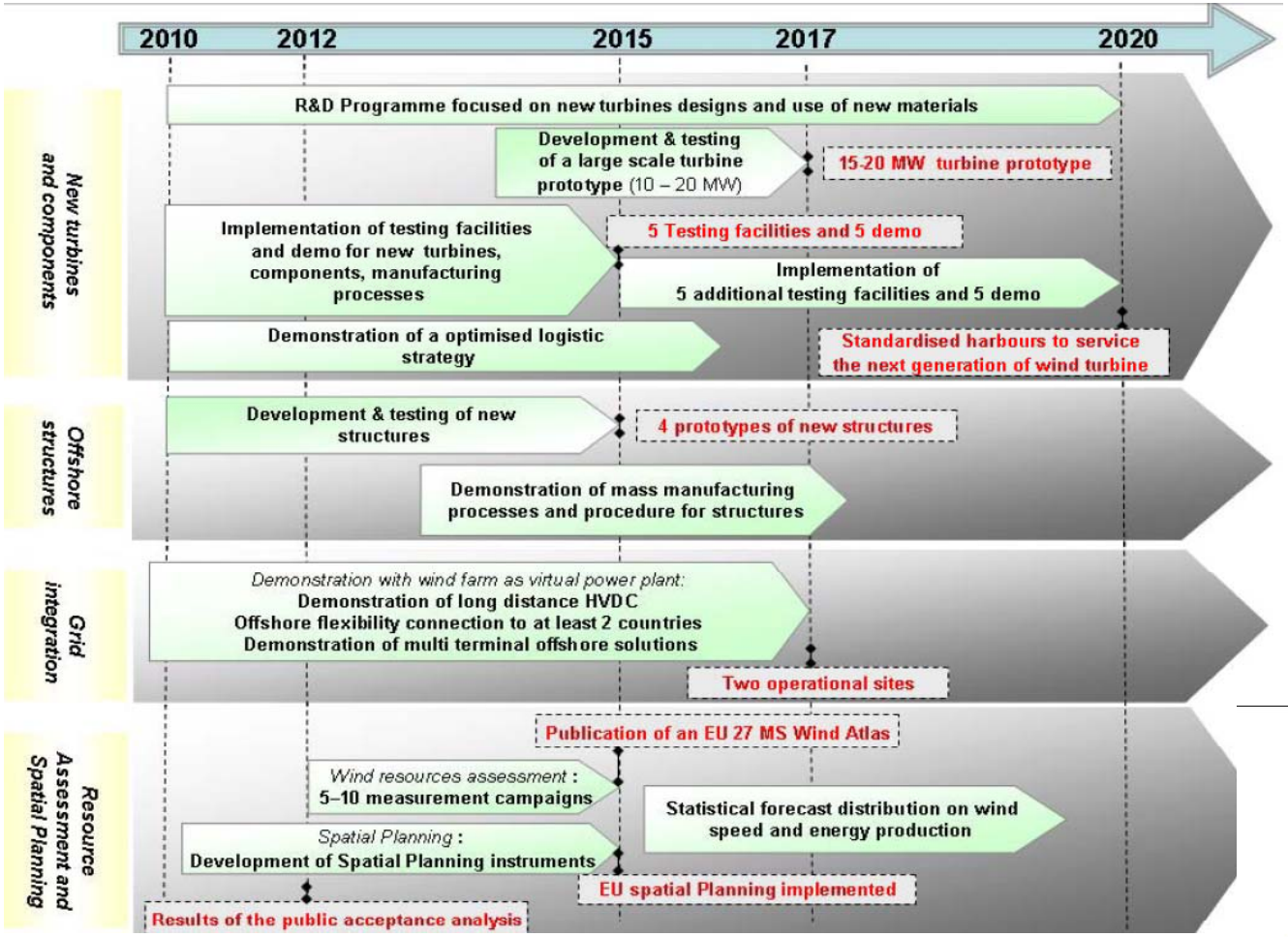
Power fluctuations

- offshore more than onshore
- power gradients of 15MW/min
- from 0 to 160MW in 10-15 min**!**

Possible impact on:

- system power balancing
- deviations of the power exchanges between neighbouring countries

In global partnerships
such as e.g. TPWIND and EERA in Europe
EC SET-plan – Technology Roadmap



TPWIND JP is strategically directed towards the scientific challenges following the implementation of the SET Plan and the RES Directive:

- **Large scale integration** and
- **An accelerated offshore wind energy deployment**, including
- **Very large offshore wind turbines.**

European Wind Energy Technology Platform

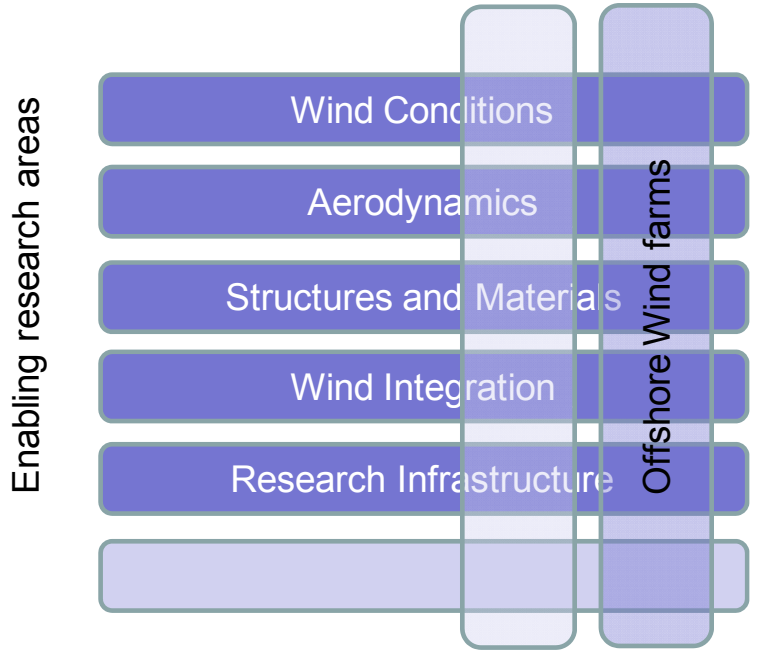
European Energy Research Alliance (EERA) JP on Wind Energy

The **Joint Programme** coordinated by Risø DTU (DK) comprises the following 5 sub-programmes:

- **Wind Conditions**. Coordinated by Risø DTU (DK).
- **Aerodynamics**. Coordinated by ECN (NL).
- **Offshore Wind Energy.** Coordinated by SINTEF (NO).
- **Grid Integration.** Coordinated by FhG IWES (DE).
- **Research Facilities**. Coordinated by CENER (ES).
- **Structures and Materials** Coordinated by CRES (HE)

- **> 175 man years** invested in joint programme activities

Application areas



Other participants
AAU (DK), DHI (DK), NTNU (NO), IFE (NO), VTT (FI), Forwind (DE)
UoS (UK), UCD (IR), WMC (NL), DUT (NL), CENERG (PL), Tubitak Uzay (TR), LNEG (PT), UoP (PT), CIEMAT (ES)
Applicants:
CNR (IT), IRUC (ES), CTC (ES) and OWI (BE)

UPWIND – EU Integrated project
completed – follow-on under preparation

Objective to develop improved design models and verification methods for wind turbine components

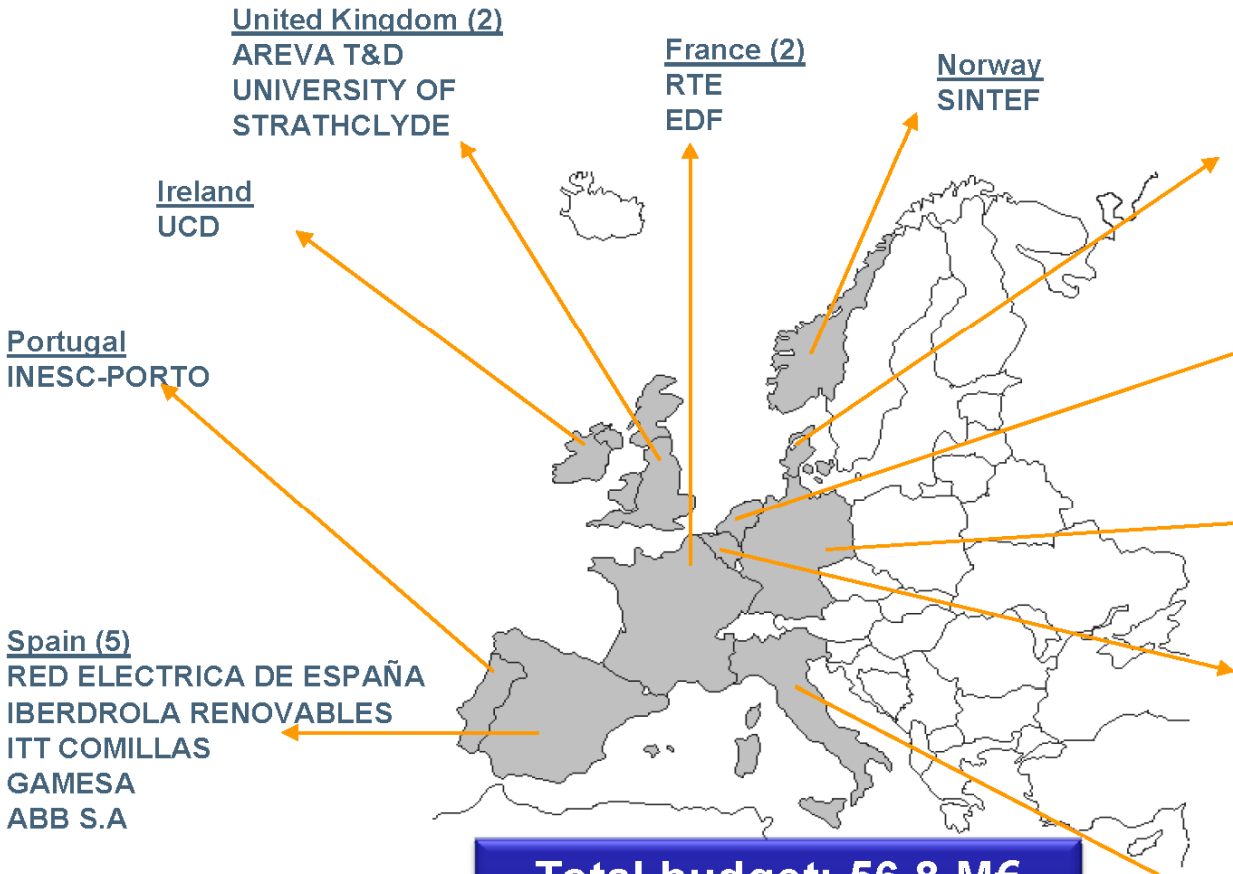
- Very Large Wind Turbines
- More Cost Efficient Wind Turbines
- Offshore wind farms of several hundred MW

- Start date: 1 March 2006
- Duration: 60 months
- Costs: 22,340,000 EUR
- EC funding: 14,288,000 EUR
- Coordinator Risø DTU, 39 part.

- 11 EU countries
- 10 research institutes
- 11 universities
- 7 turbine & component manufacturers
- 6 consultants & suppliers
- 2 wind farm developers
- 2 standardization bureaus
- 1 branch organisation

Consortium and budget

- ✓ 10 European Member States
- ✓ 1 Associated Country



United Kingdom (2)
AREVA T&D
UNIVERSITY OF STRATHCLYDE

France (2)
RTE
EDF

Norway
SINTEF

Denmark (3)
DONG ENERGY
ENERGINET
RISO DTU

Ireland
UCD

Portugal
INESC-PORTO

The Netherlands
TENNET

Germany (3)
Fraunhofer IWES
50 Hz
SIEMENS Wind Power

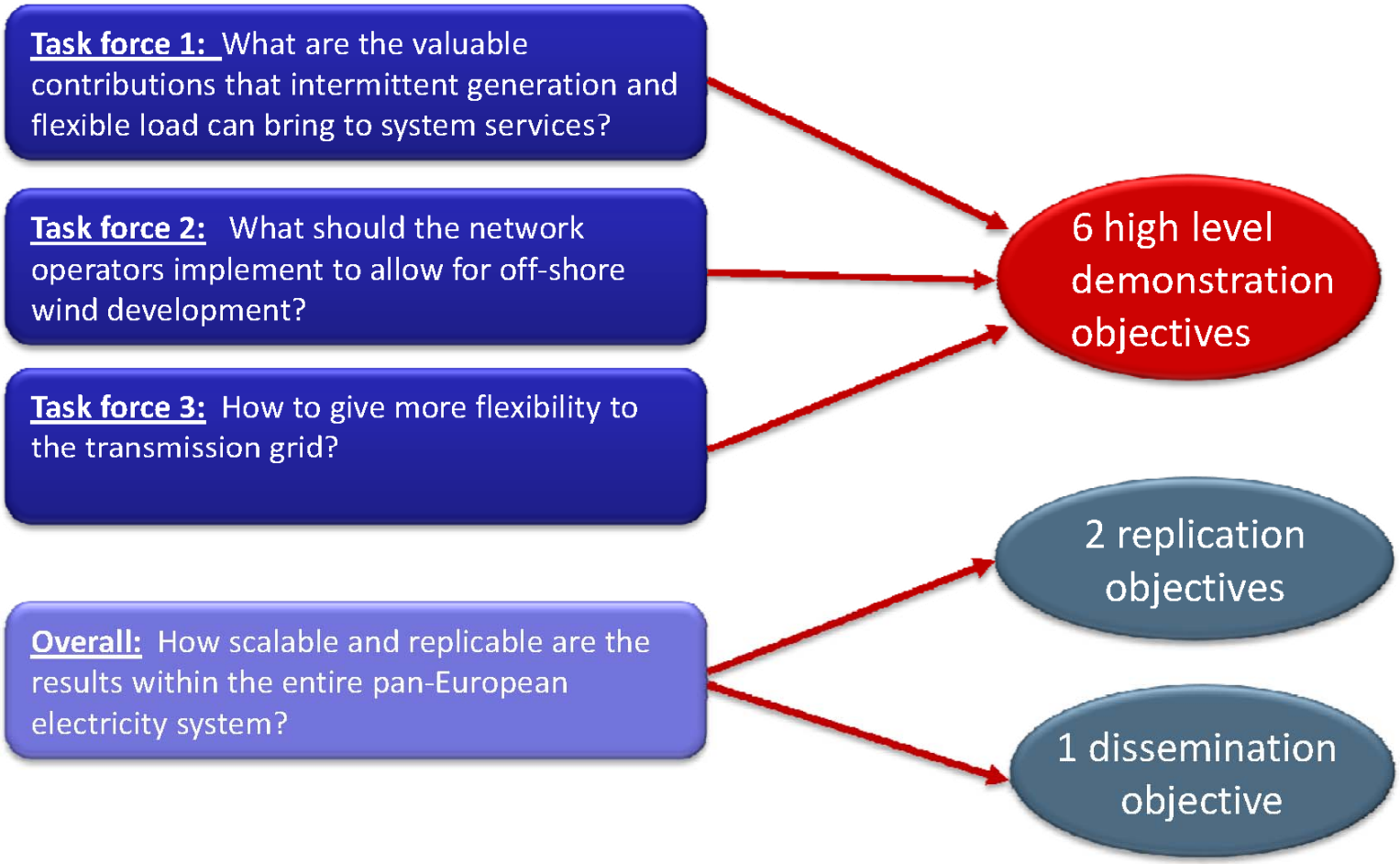
Spain (5)
RED ELECTRICA DE ESPAÑA
IBERDROLA RENOVABLES
ITT COMILLAS
GAMESA
ABB S.A

Belgium (6)
ELIA System Operator
EWEA
CORESO
UNIVERSITY LIEGE
UNIVERSITY LEUVEN-ELECTA
UNIVERSITE LIBRE BRUXELLES

Italy
ERSE

Total budget: 56,8 M€
EU contribution: 31,8 M€

Project objectives



SINO-DANISH CENTRE FOR EDUCATION AND RESEARCH
中国丹麦科研教育中心

Wind energy 风能

- 4 Ph.D. scholarships, 2011-2014:
  - Ph.D. scholarship on advanced control of wind power conversion system. Candidate to be selected (AAU and IEE CAS)
  - Ph.D. scholarship on wind farm integration. Candidate to be selected (AAU and IEE CAS)
  - Ph.D. scholarship on dynamic modelling and ancilliary services in large scale wind power. Candidate has been selected (Risø DTU, IEE CAS and CEPRI)
  - Ph.D. scholarship on coordinated control of wind power plants and storage systems. Candidate to be selected (DTU Electrical Engineering and IEE CAS)
- Joint SDC paper "Research Developments on Power System Integration of Wind Power" to be presented at China Wind Power 2011
- Joint research proposal (DSF, MOST)

The Bolund Experiment

A. Bechmann, P-E Rethore, N.N. Sørensen, J. Berg, H.E. Jørgensen, J. Mann, M. Courtney, P. Hansen, J. Johansen, K. Enevoldsen, L. Christensen, M. Rasmussen, S. Lund, S. Berner, K. Clemmensen, P. Hummeshøj, R. Kjærsgaard, A. Sogachev, S. Sørensen, A Jørgensen

Risø DTU
National Laboratory for Sustainable Energy
Risø DTU, Technical University of Denmark

Vestas

Purpose of Blind Comparison

1. **Make The Bolund Data Visible**
2. **Evaluate Flow Modeling Accuracy**
3. **Standardize Resource Assessment Modeling?**

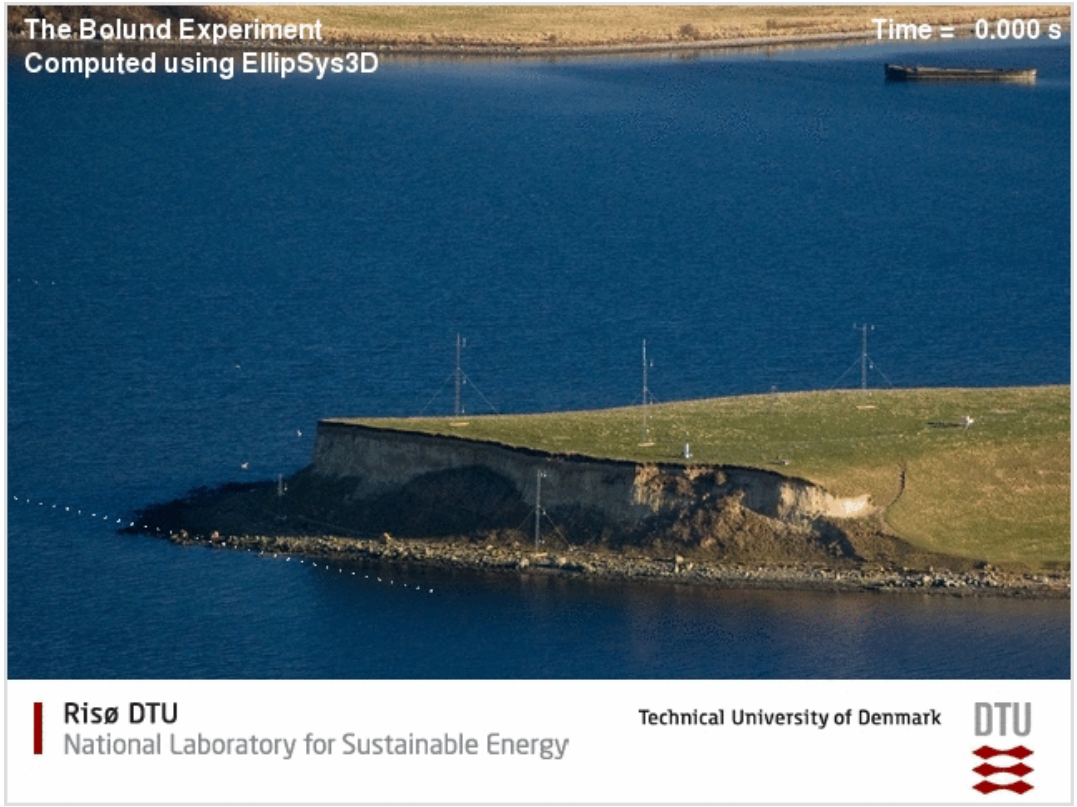
Conclusions

The Experiment

1. Instrumentation and data acquisition worked well. Proximity to Risø – convenient

2. We have successfully captured the gross features of flow over a steep hill

3. Important to plan the experiment using the tools that are being validated



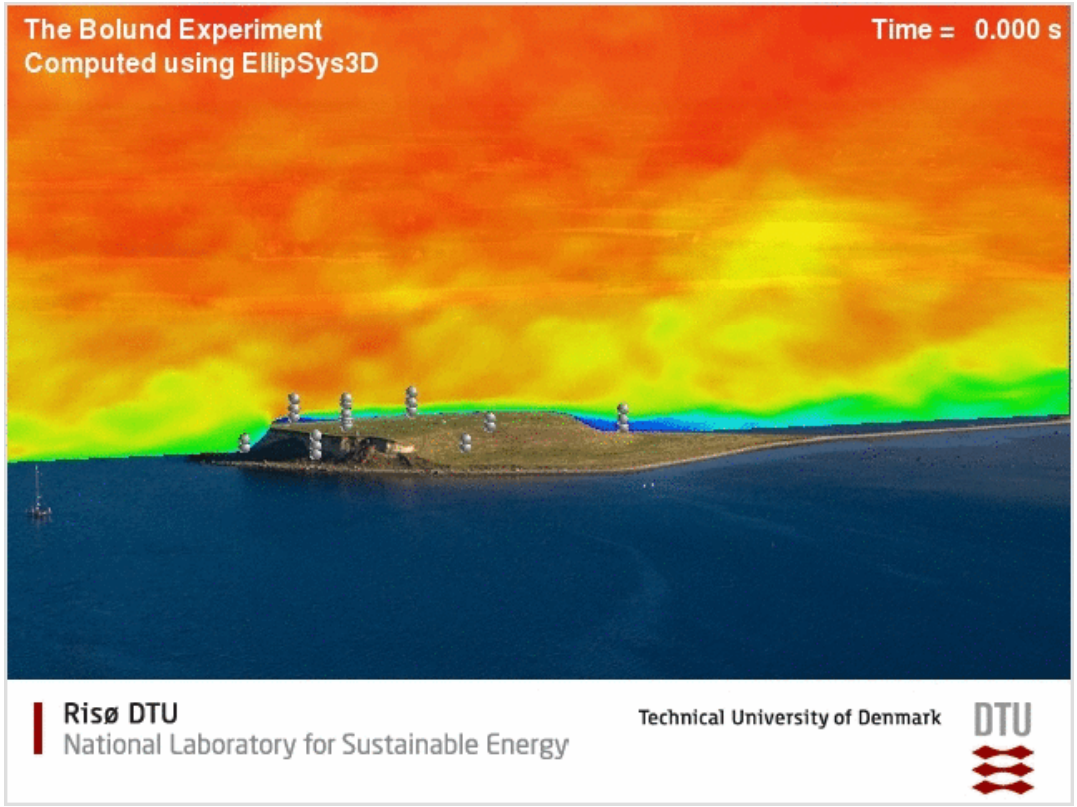
Conclusions

The Blind Comparison

1. Recommendation: RANS k-ε is today's main workhorse, LES has not matured yet.

2. 10% error on speed-up and 20% on TKE is what to expect in complex terrain?

3. 7 diff. CFD solvers in top 10: The user is more important than the solver.



Boundary-Layer Meteorology

Most downloads in September 2011

303	The Bolund Experiment, Part II: Blind Comparison of Microscale Flow Models Bechmann, A.; Sørensen, N. N.; Berg, J. Show all authors (5)
188	The Bolund Experiment, Part I: Flow Over a Steep, Three-Dimensional Hill Berg, J.; Mann, J.; Bechmann, A. Show all authors (5)
135	The Near-Calm Stable Boundary Layer Mahrt, Larry
108	A Wind-Tunnel Investigation of Wind-Turbine Wakes: Boundary-Layer Turbulence Effects Chamorro, Leonardo P.; Porté-Agel, Fernando
83	Modelling Near-Surface Low Winds over Land under Stable Conditions: Sensitivity Tests, Flux-Gradient Relationships, and Stability Parameters Luhar, Ashok K.; Hurley, Peter J.; Rayner, Ken N.

Thanks to

- Danish Energy Agency
- Vestas Technology R&D
- and the 60 participating companies:

3Tier	Geo-net	Tokyo Institute of Technology
ANSYS	Germanischer Lloyd	TUV Nord
Barlovento Recursos Naturales	Go Virtual Nordic AB	Univ Maryland
CENER	Kjeller Vindteknikk	Univ Berkeley
CERC	Megajoule	Univ Duke
CEsA Univ Porto	Meridian Energy	Univ Edinburgh
Chalmers Univ of Tech.	Metacomp Technologies	Univ Johns Hopkins
COWI	Meteodyn	Univ Madrid
CRES	MS Micro	Univ Nottingham
DMI Force	National Institute of Water & Atmospheric Research	Univ Southampton
ECOFYS	Natural Power	Univ Stanford
École de Technologie Supérieure	NCAR	Univ York (Toronto)
EMD	Nordex	Vattenfall
ENERCON	Normawind	Vijayant Kumar
EREDA	Numeca	Von Karman institute
ETH Zürich	RES	Wind Farm Grou
GAMESA	ReSoft ltd	Windlab Systems
Garrad Hassan	RWE npower renewables	WindSim
GE Infrastructure	Siemens Wind Power a/s	
DNV	Star-CD	
	Suzlon Wind Energy	


Thank you